Occupational Exposures to Steel Dust in the NYC Subway: Assessing the Potential for Health Impacts

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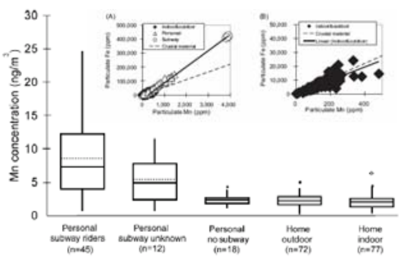
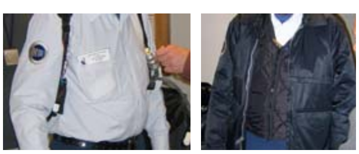
Background

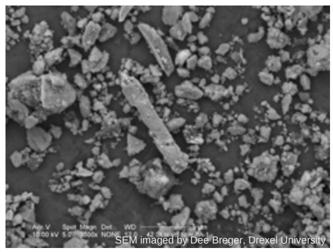
Increasingly, the subway is being recognized as an important microenvironment for air pollution research. In New York, the metals in steel dust have been detected at concentrations hundreds of times greater in the subway than at street level (Chillrud *et al.*, 2004). We conducted a study of 50 transit workers and 25 suburban office workers to determine which job activities were associated with the highest exposures to steel dust, and to evaluate the potential for health effects.



Prior work has shown the subway environment to be the dominant source of particulate metal exposure for urban high school students who use the subway (Chillrud *et* al., 2005). Iron-manganese ratios of student personal samples matched those of samples taken in the subway, indicating a common source. Iron-manganese ratios of samples taken at student's homes were consistent with crustal ratios.



Personal air samplers developed for this study were built with a low profile and worn under-the-arm beneath work jackets to minimize the risk of injury to the workers from passing trains.



- Subway particles are generated by frictional grinding of the brake shoes, wheels, and rails.
- Subway particles are rich in Iron, Manganese and Chromium
- They have a greater capacity to induce DNA damage and oxidative stress than street level particles (Karlsson *et al.*,2005).

Health Effects

The deleterious effects of particulate metal exposure at high concentrations have been documented in *in vitro*, animal, and epidemiological studies. Exposure to welding fumes is associated with diseases such as pneumonia, siderosis, and Parkinsonism. While most studies of health risks associated with manganese exposure have been in the range of 3-5 mg/m^3, symptoms of neurofunctional changes and elevated manganese levels in blood and urine have been reported at levels as low as 70 µg/m^3 (Lucchini *et al.*, 1999). The highest manganese concentrations measured in this study were 1 to 2 µg/m3. This study is the first to monitor the personal exposure of a substantial number of individuals in the subway environment, and to collect biological samples to determine whether there is a biological response, and therefore the potential for health effects, due to steel dust exposure in the subway environment.

Methods

To assess which subway workers have the highest exposure to steel dust workers were enrolled from a variety of job titles, including: train operators, train conductors, station cleaners, overhaul shop workers, construction flaggers, refuse train workers, track maintenance, and track construction workers. Subway workers carried personal air samplers for a period of one to three days. At the conclusion of the monitoring period, workers gave blood and urine samples. The levels of steel dust metals and biomarkers of oxidative stress and DNA damage in the biological samples of the exposed and control groups were compared. At the individual level, the strength of the association between worker exposure and the levels of the metals and biomarkers in their blood and urine was evaluated.

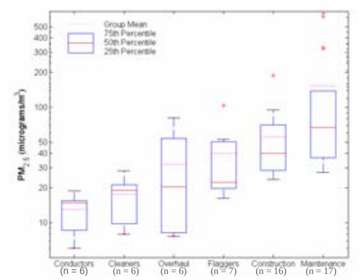
Support for this research was provided by the National Institute for Environmental Health Sciences (NIEHS) Center for Environmental Health in Northern Manhattan (P30 ES09089) and the US EPA Science to Achieve Results (STAR) Program (Grant #: 91615901-0).

We thank the members of Local 100 of the Transit Workers Union and the NYC Metropolitan Transit Authority's Office of System Safety for their collaboration. Subway photo is used with the copyright holder's permission, www.nycsubway.org.

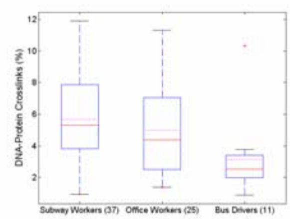
Results

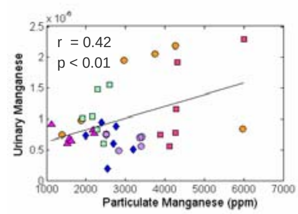
Personal Air Monitoring Results

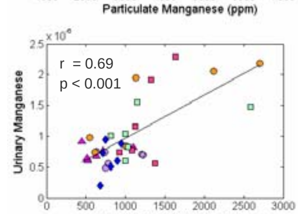
PM2.5 concentrations varied greatly on the basis of job title, as well as job activity. The mean worker exposure was 52 µg/m3, with a range of 6 µg/m3 – 469 µg/m3. Exposures for the same individuals varied by as much as 900% from one night to the next, depending on job activity. Scraping dry, impacted debris from the tracks was the dirtiest activity monitored. When the impacted material was wet, exposures were reduced 10-fold.



Track maintainers were exposed to the highest concentrations of steel dust of any group with an average individual PM2.5 concentration of 171 µg/m3. Note the log scale on the y-axis.







Biological Samples

At the population level urinary isoprostanes, a biomarker of oxidative stress, and DNA-protein complexes, a biomarker of DNA damage, were detected at significantly greater concentrations for subway workers than for bus drivers ($p < 0.01$, and $p < 0.05$, respectively). There was no significant difference between the subway workers and the control groups for mean concentrations of protein carbonyls, 8-oxodG, PAH metabolites, or trace metals in whole blood, plasma, or urine.

At the individual level none of the biomarkers measured were significantly associated with the filter metal loadings in units of mass per unit volume of air filtered (*e.g.* ng/m3). However, there were significant associations between urinary Mn, PAH metabolites, and filter metal concentrations in units of parts per million (ppm, as mass of metal per mass of PM2.5). We hypothesize that ppm metal concentration may be related to how recently the steel dust was generated. Workers with lower ppm exposures tended to mechanically disturb sedimented debris while workers with higher ppm exposures were generally exposed only to particulates already suspended in the air. Freshly generated steel particles may have more reactive surfaces, different oxidation states, and smaller diameters than aged steel dust mixed with other material such as construction dust and dirt.

Conclusions

At the population level, these results provide evidence for a possible connection between occupational exposure to steel dust and a biological response. At the individual level, there were no significant associations between common metrics of exposure and the biomarkers measured. Given that the concentrations of particulate metals were low in comparison with occupational settings where biological effects have been detected, this was not a surprising result. That metal concentrations in parts per million were found to be significantly associated with a biological response, while mass loadings in ng/m3 were not, suggests that particle size and oxidation state potentially play important roles in determining biological uptake and toxicity.

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